# Price Linkages in Asian Equity Markets and the Asian Economic, Currency and Financial Crises

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## Abstract

This paper examines the short and long-term price linkages among Asian equity markets in the period surrounding the recent Asian economic, financial and currency crises. Three developed markets (Hong Kong, Japan and Singapore) and six emerging markets (Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand) are included in the analysis. Multivariate cointegration procedures, Granger-causality tests and generalised variance decomposition analyses based on error-correction and vector autoregressive models are conducted to examine long and short-run relationships among these markets. The results indicate that there is a stationary long-run relationship and significant short-run causal linkages between the Asian equity markets. Furthermore, the long-run interrelationships have strengthened since the onset of the Asian crises. Nevertheless, lower causal relationships that exist between the developed and emerging equity markets suggest that opportunities for international portfolio diversification in Asian equity markets still exist.

*Keywords:* Financial integration, international portfolio diversification, market efficiency.

*JEL classification:* C32, F36, G15.

## 1. Introduction

Following the massive devaluation of the Thai baht in July 1997, most East Asian and South-East Asian financial markets, particularly in Korea, Malaysia, Indonesia and the Philippines, experienced similarly dramatic devaluations in exchange rates. In these markets managed currencies were allowed to move in a wider band or abandoned altogether, capital control measures were introduced, bank and sovereign ratings were downgraded, and inflationary expectations revised upward along with unemployment. As the crises intensified, foreign exchange and stock market turmoil spread across Asia. News of economic and political distress, particularly bank and corporate fragility, became commonplace, and modest recoveries in some markets were repeatedly assailed by deteriorating conditions in others. Only by mid 1999 was Asian recovery becoming a reality, and only after extensive microeconomic reform, fiscal contraction and international financial assistance. Nevertheless, the pace of Asian recovery is exceedingly slow and uneven. While some economies, such as Korea, have made moderate gains in 1999/2000, they are followed at a distance by many, including Thailand, the Philippines, Hong Kong and Singapore, and yet further behind by

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several of the markets most distressed by the regional collapse, especially Malaysia and Indonesia.

Quite apart from the posited macroeconomic, structural and policy origins of the Asian economic, currency and financial crises, the manner in which these crises reverberated across national stock markets has created considerable interest in the study of linkages among regional capital markets. This is especially noteworthy since Asian capital markets have been traditionally viewed as being relatively isolated from each other. However, with the Asian crises came the realisation that the several capital markets had becomes so integrated that the more developed markets, including Singapore and Hong Kong, exerted a strong influence on the smaller markets, especially Indonesia, Malaysia and Thailand. Indeed, the more developed markets themselves were no longer isolated from conditions in the emerging markets.

The growing integration of Asian financial markets has obvious implications for international portfolio diversification. Starting with the seminal studies of Levy and Sarnat (1970) and Solnik (1974) a voluminous empirical literature has arisen concerned with establishing the degree of correlation in international capital (equity) markets. If, and as has been hypothesised, low correlations of returns exist, diversifying across national markets allows investors to reduce portfolio risk while holding expected return constant. This would appear to have been a major factor in the interest international investors expressed in Asian emerging markets before the crises. As an indication, net portfolio investment flows averaged $US10.5 billion for the period 1991 to 1996 across Asia, and $US11.75 billion in the five economies most affected by the crises (namely, Indonesia, Korea, Malaysia, the Philippines and Thailand) (Baig and Goldfajn 1998: 93).

Unfortunately, little empirical evidence exists concerning short and long-term linkages among Asian capital markets and the concomitant prospects for international portfolio diversification. International studies concerned with market linkages are relatively commonplace [see, for example, Arshanapalli and Doukas (1993), Masih and Masih (1999) and Cheung and Lai (1999)]. And regional markets, especially in Europe (Abbott and Chow 1993; Espitia and Santamaria 1994; Akdogan 1995; Meric and Meric 1997) and Latin America (Chaudhuri 1997; Christofi and Pericli 1999) are subject to increasing attention. However, few studies have adopted an Asian regional perspective. Moreover, even where Asian markets are examined in a broader multilateral context (that is, along with North American and European markets) there is generally an emphasis on the more developed Asian economies. For example, Lai *et al.* (1993), Richards (1995) Solnik *et al*. (1996), Darbar and Deb (1997), Yuhn (1997) and Francis and Leachman (1998) only incorporated Japan in their studies of international stock market linkages, Ramchand and Susmel (1998) added Singapore and Hong Kong, while Kwan *et al*. (1995) also included Taiwan and Korea. As far as the authors are aware, no study to date has examined capital market linkages across the broad spectrum of Asian developing and developed economies, irrespective of any changes arising from the recent economic, currency and financial crises.

The paper itself is divided into four main areas. The second section briefly surveys the empirical literature concerning price linkages and international portfolio diversification in the Asian milieu. The third section explains the methodology and data employed in the present analysis. The results are dealt with in the fourth section. The paper ends with some brief concluding remarks.

## 2. Asian equity market linkages

Despite their generally small size in terms of global market capitalisation, Asian equity markets have increasingly attracted non-Asian investors – particularly from the U.S. – to the potential benefits of international diversification. However, it has been cogently argued [see, for example, Roca (1999) and Masih and Masih (1999)] that comparatively recent developments in these markets, including increasing levels of trade interaction and the easing of regulatory restrictions governing the movement of capital, have diminished the prospects for diversification by these groups. Combined with the pace of global financial integration, and innovations such as the October 1987 stock market crash and the more recent Asian crises, these factors suggest that Asian capital markets have become increasingly integrated.

Several studies have been undertaken which focus upon the relationships between developed and emerging Asian markets. In one of the earlier studies, Bailey and Stulz (1990) examined the prospects for international portfolio diversification among Pacific Basin stock markets. Using daily returns for the Hong Kong, Japan, Malaysia, Philippines, Singapore, Korea, Taiwan and Thailand stock market indexes over the period January 1977 to December 1985, and specifying their analysis in US dollars, Bailey and Stulz (1990) employed simple correlation analysis to detect significant interrelations among markets. The results indicated that the degree of correlation between US and Asian equity returns depended upon the periodic specification, whether daily, weekly or monthly. For example, with daily returns only the correlations between the US and Hong Kong, Japan and Taiwan were significant, while for monthly returns all Asian market correlations were significant, with the exception of the Philippines and Thailand. Using this evidence Bailey and Stulz (1990: 61) concluded that the benefits for US investors diversifying into the Pacific Basin were "…substantial and yet they are easily overestimated [when] using daily data [or] for investors with holding periods longer than one day".

Specifying a similar set of Asian equity markets, Cheung and Mak (1992) also used national share market indices to analyse financial integration, though defined in terms of weekly returns over the period January 1977 to June 1988. The approach to international portfoio diversification was likewise from a US investor perspective. Employing an ARIMA model Cheung and Mak (1992: 46) found:

> [O]ur study provides evidence that the US stock market leads most of the Asian-Pacific stock markets with the exception of the three relatively closed markets [Taiwan, Korea and Thailand]. Similar testing procedures are also performed to examine the causal relationship between the Japanese market and other smaller Asian emerging markets…the regional factor [Japanese market] seems to have a less significant impact on the Asian-Pacific markets.

Upon this basis, Cheung and Mak (1992) concluded that opportunities still existed for portfolio diversification in Asia by international investors. In common with Cheung and Mak (1992), Janakiramanan and Lamba (1998) examined Asian emerging markets in the broader context of the Pacific-Basin [that is, along with the United States, Australia and New Zealand]. The results of a vector autoregression (VAR) model provided evidence "…that markets that are geographically and economically close and/or have large numbers of cross-border listings exert significant influence over each other". Importantly, while the US market was obviously the most influential market, Janakiramanan and Lamba (1998) found that its effect had diminished over more recent years in favour of regional influences.

In contrast to the work of Bailey and Stulz (1990) and Cheung and Mak (1992), more recent analyses of Asian financial market interrelationships have employed cointegration techniques.

For example, Chung and Liu (1995) used weekly national index data from the Japanese, Taiwanese, Hong Kong, Singaporean and Korean markets in conjunction with cointegration tests to examine long-run relationships over the period January 1985 to May 1992. Chung and Liu (1994: 257) found that "…stochastic trends dictated by the four common unit roots are important to the long-run movement of the stock prices". The results also indicated that Taiwan (along with the US) did not belong to the same common stock region as the remaining four countries (namely, Japan, Singapore, Hong Kong and Korea) (Chung and Liu 1994).

Kwan *et al*. (1995) also used cointegration analysis to examine long-term links between world equity markets (including Japan, Taiwan, Korea, Singapore and Hong Kong) as well as Granger causality tests to quantify short-term causal relationships. The sample spanned the period January 1982 to February 1991 and like much of the work in this area used commonly available stock market indices. For example, the four Asian indices used were the Nikkei Dow (Japan), Hang Seng (Hong Kong), Taiwan Weighted, South Korea Composite and Singapore Strait Times. Focusing on the 'four little tigers' Kwan *et al*. (1995) concluded "…a (uni-directional) causal sequence is found in all but 4 of 12 cases considered and that the existence of significant lead-lag relationships between equity markets points to a rejection of the informational market efficient hypothesis". Roca (1999) used similar techniques to investigate short and long-term price linkages between Asian equity markets over the period December 1974 to December 1995, and made allowance for the structural shifts associated with the 1987 stock market crash. However, contrary to the findings of Kwan *et al*. (1995), Roca (1999: 510) found evidence suggesting that "the lack of cointegration between the equity markets of Australia and the US, UK, Hong Kong, Singapore, Taiwan and Korea means that the latter markets could serve as good avenues for long-term portfolio diversification".

Nevertheless, evidence concerning Asian financial market integration has been more mixed when samples have either included smaller emerging markets. For example, Elyasiani *et al.* (1998) examined the interdependence and dynamic linkages between the Sri Lankan stock market and its trading partners. The Asian trading partners were comprised of Taiwan, Singapore, Japan, South Korea, Hong Kong and India. Elyasiani *et al*. (1998: 100) concluded:

> Overall, the results on the dynamic responses to external shocks demonstrate that the Sri Lankan market is very much immune to shock originating form the US and six Asian countries considered here with whom it has a trading relationship. It appears that the emerging capital market of Sri Lanka is scantily integrated with those of the larger and stronger economies of the region.

Accounting for these differences between emerging markets and larger regional economies, Elyasiani *et al*. (1998) reasoned that low levels of capitalisation, a lack of market liquidity, high concentration in blue chips and barriers to investment were possible reasons for the lack of interdependence. And these therefore provided opportunities for diversification benefits to global investors.

Lastly, there is some evidence that there is strong regional perspective to Asian capital market interrelationships. For instance, Masih and Masih (1999: 275) found that "…other advanced countries did not appear to have any pronounced effect on the Asian regional markets (compared to the intra-regional impact of the Asian markets". Put differently, "…the results tend to lend strong support to the view that the stock market fluctuations in all these Asian markets are explained mostly by their regional markets (rather than the advanced economies) (Masih and Masih: 251). Masih and Masih (1999) attributed the increasingly strong Asian intra-regional stock market dependency to *inter alia* growing shares of intra-regional trade and investment and common monetary policies pursued since the October 1987 crash.

The existing literature regarding the degree of Asian financial market interdependence and the concomitant potential for international portfolio diversification may be summarised as follows. First, most empirical studies to date have indicated that the major equity markets (ie. Japan, Hong Kong, Taiwan and Korea) are closely integrated, thereby diminishing the potential for Asian portfolio diversification. This holds for both studies with a specific Asian focus and those examined in a broader international context [see, for example, Kwan *et al*. (1995), Elyasiani *et al*. (1998) and Masih and Masih (1999)]. However, evidence concerning financial integration in some of the smaller Asian equity markets (ie. Thailand, the Philippines, Indonesia and Malaysia) is less conclusive.

Second, evidence also exists that the degree of financial interrelationship among Asian markets has increased dramatically in recent years. Key aspects of this process have been increasing shares of intra-regional trade and investment, and the impact of innovations in the form of market shocks such as the October 1987 stock market crash (Roca 1998; Masih and Masih 1999). However, no study to date has addressed the possible impact of the 1997 Asian crises on these relationships. Third, while some evidence exists concerning financial integration in other regional markets, especially Europe, far less is known about financial interrelationships in the Asian region. This is particularly pertinent because of the large number of emerging markets in the region and the generally strong growth potential, but also because of the hitherto unexpected contagion effects that characterised the regional economy in 1997/98.

Finally, while more recent work has taken advantage of the sizeable advances in cointegration techniques, much of the work on Asian financial market interrelationships has been constructed using simple correlation techniques. Moreover, most of the data used in these analyses are drawn from national stock market indices which may exhibit particular problems associated with the degree of comparability with respect to index breadth, liquidity and construction. Combined together, these factors may serve to comprise existing work in this area.

## 3. Empirical methodology

The data employed in the study is composed of value-weighted equity market indices for nine Asian markets; namely, Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. Three of these markets are categorised as ‘developed’ (Hong Kong, Japan and Singapore) and the remainder is regarded as ‘emerging’. All data is obtained from Morgan Stanley Capital International (MSCI) and encompasses the period 1 January 1988 to 18 February 2000. MSCI indices are widely employed in the financial integration literature on the basis of the degree of comparability and avoidance of dual listing [see, for instance, Meric and Meric (1997), Yuhn (1997), Roca (1999) and Cheung and Lai (1991)]. Weekly data is specified. On one hand, it has been argued that “daily return data is preferred to the lower frequency data such as weekly and monthly returns because longer horizon returns can obscure transient responses to innovations which may last for a few days only” (Elyasiani *et al*. 1998: 94). However, Roca (1999: 505), amongst others, have countered that “…daily data are deemed to contain ‘too much noise’ and is affected by the day-of-the-week effect”.

Within this data set, three time-series sub-periods are identified. The sub-periods consist of the period leading up to the onset of the Thai currency crisis (1/1/1988–25/7/97), a period since this event (1/8/1997–18/2/2000), and the entire sample (1/1/1988–18/2/2000). The overall hypothesis is that existing short and long-term price linkages have strengthened in the period since the beginning of the Asian crises period, and that regional financial interrelationships are also more extensive in this period.

The paper investigates the integration among Asian equity markets as follows. To start with, since the variance of a nonstationary series is not constant over time, conventional asymptotic theory cannot be applied for those series. Unit root tests of the null hypothesis of nonstationarity are conducted in the form of an Augmented Dickey-Fuller (ADF) regression equation:

$$\Delta Y_{it} = \alpha_0 + \alpha_1 t + \rho_0 Y_{it-1} + \sum_{i=1}^{p} \rho_i \Delta Y_{it-i} + \varepsilon_{it} \tag{1}$$

where $Y_{it}$ denotes the index for the $i$-th country at time $t$, $\Delta Y_{it} = Y_{it} - Y_{it-1}$, $\rho$ are coefficients to be estimated, $p$ is the number of lagged terms, $t$ is the trend term, $\alpha_1$ is the estimated coefficient for the trend, $\alpha_0$ is the constant, and $\varepsilon$ is white noise. The critical values in MacKinnon (1991) are used in order to determine the significance of the test statistic associated with $\rho$. ADF tests for a deterministic trend are employed, and performed on both the levels and first differences of the indices. Where each index is nonstationary in levels and stationary in first differences, it may be concluded that the indices are individually integrated of order 1, I(1). An important property of I(1) variables is that there can be a linear combination of these variables that are I(0) (stationary). If this is so, then these variables are cointegrated such that there is some tendency for the two series in the long run not to drift too far apart (or move together).

Following Engle and Granger (1987) suppose we have the set of $m$ indices $y_t = [Y_{1t,} Y_{2t}, \cdots, Y_{mt}]'$ such that all are I(1) and $\beta' y_t = u_t$ is I(0), then $\beta$ is said to be a cointegrated vector and $\beta' y_t = u_t$ is called the cointegrating regression. The components of $y_t$ are said to be cointegrated of order $d$, denoted by $y_t$ ~ CI($d$, $b$) where $d > b > 0$, if (i) each component of $y_t$ is integrated of order $d$, and (ii) there exists at least one vector $\beta = (\beta_1, \beta_2, \ldots, \beta_m)$, such that the linear combination is integrated of ($d$ - $b$). By Granger's theorem, if the indices are cointegrated, they can be expressed in an Error Correction Model (ECM) encompassing the notion of a long-run equilibrium relationship and the introduction of past disequilibrium as explanatory variables in the dynamic behaviour of current variables. This model thus allows a test for both short-term and long-term relationships between the indices. The ECM is specified as follows:

$$\Delta y_t = a_0 + \Pi y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \tag{2}$$

where , $\Pi = \alpha\beta'$, $\alpha$ and $\beta$ are $m \times r$ matrices, $\Gamma$ is the coefficients of the lagged difference terms, and all other variables are as previously defined. In (2) the long-run relationship is captured by $\beta' y_t$, and the differenced terms and the terms which are adjusted by the long-run relationship (the summation term on the right-hand side) capture the short-run relationship.

In order to implement the ECM, the order of cointegration must be known. A useful statistical test for determining the cointegration order $r$ is proposed by Johansen (1991) and Johansen and Juselius (1993). The test is based on the MLE and the rank of $\Pi$ (denoted by $r$) is tested based on its eigenvalues. Two tests viz. the maximum eigenvalue test and trace test, are proposed. In the trace test, the test statistic is:

$$\lambda(r) = -T\sum_{i=r+1}^{m}\ln(1-\lambda_i) \tag{3}$$

where $\lambda_i$ denotes the *i*-th greatest eigenvalues of $\hat{\Pi}$ and $T$ is the number of useable observations. The test statistic (3) tests the null hypothesis on the number of distinct cointegrating vectors such as $r = 0$ versus $r > 0$, $r \leq 1$ and so on. For example, to test for no cointegrating relationship, $r$ is set to zero and the null hypothesis is $H_0 : r = 0$ and the alternative is $H_1 : r > 0$. Critical values for these statistics are tabulated in Osterwald-Lenum (1992).

However, the Johansen (1991) test can be affected by the lag order $k$ in (2). The lag order is determined by using both the likelihood ratio (LR) test and information criteria in VAR. The optimum number of lags to be used in the VAR models is determined by the likelihood ratio (LR) test statistic:

$$LR = (T-K)\ln\left(|\Sigma_0| / |\Sigma_A|\right) \tag{4}$$

where $T$ is the number of observations, $K$ denotes the number of restrictions, $\Sigma$ denotes the determinant of the covariance matrix of the error term, and subscripts *0* and *A* denote the restricted and unrestricted VAR, respectively. LR is asymptotically distributed $\chi^2$ with degrees of freedom equal to the number of restrictions. The test statistic in (4) is used to test the null hypothesess of the number of lags being equal to $k - 1$ against the alternative hypotheses that $k = 2, 3, \ldots$ and so on. The test procedure continues until the null hypothesis fails to be rejected, thereby indicating the optimal lag corresponds to the lag of the null hypothesis.

Finally, in order to examine the short-run relationships, Granger (1969) causality tests are specified. Essentially tests of the prediction ability of time series models, an index causes another index in the Granger sense if past values of the first index explain the second, but past values of the second index do not explain the first. If the indices in question are cointegrated, Granger causality is tested using the ECM:

$$\Delta y_t = \gamma_0 + \sum_{i=1}^{r}\psi_i\Theta_{t-1} + \sum_{i=1}^{m}\gamma_i\Delta y_{t-i} + \varepsilon_t \tag{5}$$

where $\Theta$ contains $r$ individual error-correction terms, $r$ are long-term cointegrating vectors via the Johansen procedure, $\psi$ and $\gamma$ are parameters to be estimated, and all other variables are as previously defined. If there is no cointegrated relationship, the causality tests are conducted using the following VAR model:

$$\Delta y_t = \gamma_0 + \sum_{i=1}^{m}\gamma_i\Delta y_{t-i} + \varepsilon_t\ . \tag{6}$$

In both cases, the causality test is based on an *F*-statistic that is calculated using the constrained and unconstrained form of each equation. If the hypothesis $\gamma_{ijl} = 0\,(i = 1,2,\cdots,m)$ fails to be rejected the *j*-th index does not Granger cause the *l*-th index, and current changes in *l*-th index cannot be explained by changes in the *j*-th index. If the hypothesis is rejected, the *j*-th country Granger-causes the *l*-th country and current changes in the *l*-th index can be explained by past changes in the *j*-th index, thereby indicating a casual relationship.

One limitation of these tests is that while they indicate which markets Granger-cause a given market, they do not indicate whether yet other markets can influence a given market through other equations in the system. Likewise, Granger causality does not provide an indication of the dynamic properties of the system, nor does it allow the relative strength of the Granger-causal chain to be evaluated. However, decomposition of the variance of forecast errors of a given market allows the relative importance of the variance markets in causing fluctuations in that market to be ascertained. The decomposition process therefore allows the variance of the forecast errors to be divided into percentages attributable to innovations in all other markets and a percentage attributable to innovations in the given market. One problem here is that the decomposition of variances is sensitive to the assumed origin of the shock and to the order it is transmitted to other markets. To overcome this problem, a generalised impulse response analysis, which is not subject to any arbitrary othogonalisations of innovations in the system, is applied (Masih and Masih 1999).

## 4. Empirical results

Table 1 presents the ADF unit root tests (1) for the nine Asian equity indices in price level and price-differenced forms. The first column (A) for each functional form presents tests carried out for period 1/1/1988 to 25/7/1997 (prior to the onset of the Asian currency crises). The second column (B) details the tests for the period since this event; that is, 1/1/1988 to 18/2/2000. The final column (C) provides the tests for the entire sample period (1/1/1988 to 18/2/2000). In all instances, the null hypothesis of nonstationarity is tested. Analysis of the price levels series indicates non-stationarity for all markets except Indonesia in the three sample periods.

TABLE 1. *Augmented Dickey-Fuller (ADF) unit root tests*

| | | Levels series | | | First differenced series | | | Second differenced series | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | A | B | C | A | B | C |
| Hong Kong | HON | -2.5795 | -2.1307 | -2.7227 | ***-6.9567 | -2.8363 | ***-6.8037 | – | ***-4.4527 | – |
| Indonesia | IND | -2.4317 | **-3.7048 | -2.4523 | ***-6.3859 | -2.8537 | ***-6.8999 | – | ***-4.9577 | – |
| Japan | JAP | -2.0631 | -2.0163 | -2.0386 | ***-6.6988 | -2.8620 | ***-7.3920 | – | ***-5.2328 | – |
| Korea | KOR | -1.8646 | -2.6842 | -2.2467 | ***-5.7644 | -2.4390 | ***-6.1026 | – | ***-4.2709 | – |
| Malaysia | MAL | -2.7096 | -2.5983 | -1.8883 | ***-6.4086 | -2.4581 | ***-6.3833 | – | ***-4.4857 | – |
| Phillipines | PHI | -1.5223 | -3.2619 | -1.2058 | ***-6.1673 | **-3.0891 | ***-6.7382 | – | ***-3.7889 | – |
| Singapore | SIN | -1.6792 | -2.0961 | -1.9536 | ***-6.2295 | -2.6319 | ***-6.4381 | – | ***-4.8402 | – |
| Taiwan | TAI | -2.2577 | -1.3325 | -2.9359 | ***-5.2999 | **-3.0833 | ***-6.1382 | – | ***-4.6835 | – |
| Thailand | THA | -0.3648 | -3.2011 | -1.0928 | ***-5.8083 | -2.8034 | ***-6.5208 | – | ***-4.9965 | – |
| Crit. value | .01 | -3.9812 | -4.0288 | -3.9774 | -3.4461 | -3.4800 | -3.4434 | – | -3.4800 | – |
| Crit. value | .05 | -3.4210 | -3.4437 | -3.4192 | -2.8678 | -2.8830 | -2.8665 | – | -2.8830 | – |
| Crit. value | .10 | -3.1329 | -3.1464 | -3.1318 | -2.5701 | -2.5781 | -2.5694 | – | -2.5781 | – |

Notes: Period A 1/1/1988–25/7/1997, Period B 1/8/1997–18/2/2000, Period C 1/1/1988–18/2/2000; hypotheses $H_0$: unit root, $H_1$: no unit root (stationary); the lag orders in the ADF equations are determined by the significance of the coefficient for the lagged terms; for the price levels series intercepts and tends are included; for the first and second price differenced series only intercepts are included; asterisks denote significance at the *** – .01, ** – .05 and * – .10 percent level.

However, all of the ADF test statistics are significant in first differenced form for Period A, indicating stationarity and the suggestion that each index series is integrated of order 1 or I(1). A similar indication is obtained for the longest time-series (Period C). For the time-series since the onset of the Asian currency crisis (Period B) the ADF tests indicate that only the Philippines and Taiwan are non-stationary in first-differenced form. Accordingly, all market index series are recalculated in second-differenced form for this period and the null hypotheses of nonstationarity are rejected at the .01 level. The finding of non-stationarity in levels and stationarity in differences provides comparable Asian evidence to Elyasiani *et al.* (1998) and Masih and Masih (1999) amongst others. The differenced series will be used to carry out lag length selection, causality tests and decomposition of the forecast error variance for the markets analysed.

Johansen cointegration tests are used in order to obtain the cointegration rank. Eigenvalues and trace test (3) statistics are detailed in Table 2 for the various null and alternative hypotheses. As multivariate cointegration tests the results cover all markets rather than simple bivariate combinations. They therefore consider the wide range of portfolio diversification options available to non-Asian investors, as well as the scope of financial integration that may not be reflected in pairwise combinations. Three sets of tests are included. The first group of tests corresponds to the period preceding the onset of the Asian currency crisis. Critical values for these statistics are obtained from Osterwald-Lenum (1992) and are detailed in Table 2.

TABLE 2. *Johansen cointegration tests*

| | | | A | | | B | | | C | |
|---|---|---|---|---|---|---|---|---|---|---|
| $H_0$ | $H_1$ | Eigenval. | Trace | Crit. | Eigenval. | Trace | Crit. | Eigenval. | Trace | Crit. |
| r = 0 | r > 0 | 0.1204 | **246.266 | 222.210 | 0.6364 | **522.535 | 182.820 | 0.0894 | **236.602 | 222.210 |
| r ≤ 1 | r > 1 | 0.0912 | 182.365 | 182.820 | 0.5635 | **389.004 | 146.760 | 0.0735 | 177.393 | 182.820 |
| r ≤ 2 | r > 2 | 0.0727 | 134.718 | 146.760 | 0.4829 | **279.573 | 114.900 | 0.0531 | 129.127 | 146.760 |
| r ≤ 3 | r > 3 | 0.0516 | 97.110 | 114.900 | 0.4373 | **192.520 | 87.310 | 0.0431 | 94.618 | 114.900 |
| r ≤ 4 | r > 4 | 0.0410 | 70.727 | 87.310 | 0.3133 | **116.619 | 62.990 | 0.0353 | 66.744 | 87.310 |
| r ≤ 5 | r > 5 | 0.0394 | 49.885 | 62.990 | 0.2802 | **67.002 | 42.440 | 0.0259 | 44.039 | 62.990 |
| r ≤ 6 | r > 6 | 0.0283 | 29.845 | 42.440 | 0.1287 | 23.607 | 25.320 | 0.0193 | 27.430 | 42.440 |
| r ≤ 7 | r > 7 | 0.0192 | 15.569 | 25.320 | 0.0402 | 5.420 | 12.250 | 0.0167 | 15.083 | 25.320 |
| r ≤ 8 | r = 9 | 0.0118 | 5.927 | 12.250 | | | | 0.0070 | 4.421 | 12.250 |
| Accepted | | | 1 | | | 6 | | | 1 | |

Notes: Period A 1/1/1988–25/7/1997, Period B 1/8/1997–18/2/2000, Period C 1/1/1988–18/2/2000; .05 percent level critical values from Osterwald-Lenum (1992); the optimal lag order of each VAR model was selected using LR tests for the significance of the coefficient for maximum lags and Schwarz's Bayseian Information Criterion; in each cointegrating equation, the intercept (no trend) is included.

For the period up until the onset of the currency crisis (A), the trace test statistic is greater than the critical value for the null hypotheses of r = 0 thereby rejecting the null hypothesis. However, the null hypothesis of r ≤ 1 fails to be rejected in favour r > 1 indicating the order of cointegration is 1. In the time series including the period since the currency crisis (B), however, similar hypothesis are rejected up to, but not including, r ≤ 6 thereby suggesting an order of integration of 6. In the longest sample period (C), the null hypothesis of r ≤ 1 cannot be rejected. This indicates an order of integration of 1.

The primary finding obtained from the Johansen cointegration tests is that a stationary long-run relationship exists between Asian equity markets in all three time series; that is, before, after and surrounding the Asian crises. The number of long-run cointegrating relationships among Asian markets has increased in the period since the onset of the crises, thereby suggesting that the level of long-run financial integration among these markets has intensified. Further, Johansen and Juselius (1993) also point out that larger eigenvalues are associated with the cointegrating vector being more correlated with the stationary component of the underlying process, and therefore are suggestive *a fortiori* of the relative strengthening of the long run relationship.

TABLE 3. *Granger causality tests for Asian markets*

| | Market | HON | INDO | JAP | KOR | MAL | PHI | SIN | TAI | THA | Causes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Period A: 1/1/1988–25/7/1997 | HON | – | 9.8217 | 0.1415 | 1.1463 | 2.1539 | 12.2948 | 6.5019 | 0.0236 | 2.3539 | 3 |
| | | | (0.0018) | (0.7069) | (0.2848) | (0.1428) | (0.0005) | (0.0111) | (0.8778) | (0.1256) | |
| | IND | 0.0014 | – | 8.5028 | 0.7889 | 6.9673 | 0.9649 | 1.0719 | 0.1742 | 0.4728 | 2 |
| | | (0.9697) | | (0.0037) | (0.3748) | (0.0086) | (0.3264) | (0.3010) | (0.6765) | (0.4920) | |
| | JAP | 0.1386 | 0.1024 | – | 0.0276 | 2.1260 | 0.2317 | 0.0006 | 0.3079 | 0.0210 | 0 |
| | | (0.7098) | (0.7490) | | (0.8680) | (0.1455) | (0.6304) | (0.9790) | (0.5792) | (0.8847) | |
| | KOR | 7.0142 | 5.5817 | 1.8718 | – | 10.7721 | 0.4383 | 3.6269 | 2.8192 | 0.3758 | 5 |
| | | (0.0083) | (0.0185) | (0.1719) | | (0.0011) | (0.5083) | (0.0574) | (0.0938) | (0.5401) | |
| | MAL | 0.4358 | 0.1220 | 0.1470 | 3.1425 | – | 0.0017 | 0.4006 | 0.0375 | 2.5684 | 1 |
| | | (0.5094) | (0.7269) | (0.7015) | (0.0769) | | (0.9668) | (0.5270) | (0.8465) | (0.1097) | |
| | PHI | 0.2762 | 0.0026 | 0.9475 | 0.0078 | 12.0140 | – | 1.9041 | 3.9255 | 14.3450 | 3 |
| | | (0.5994) | (0.9590) | (0.3308) | (0.9293) | (0.0006) | | (0.1682) | (0.0481) | (0.0002) | |
| | SIN | 0.0501 | 2.3527 | 1.7662 | 2.5652 | 0.0727 | 0.1387 | – | 0.2770 | 0.1464 | 0 |
| | | (0.8229) | (0.1257) | (0.1845) | (0.1099) | (0.7875) | (0.7097) | | (0.5989) | (0.7021) | |
| | TAI | 0.0530 | 0.0597 | 0.8005 | 0.2645 | 0.0196 | 0.0886 | 0.1188 | – | 0.9906 | 0 |
| | | (0.8179) | (0.8069) | (0.3714) | (0.6072) | (0.8885) | (0.7660) | (0.7305) | | (0.3201) | |
| | THA | 0.6541 | 4.4592 | 2.7192 | 1.4318 | 1.1198 | 5.5120 | 1.51765 | 0.2953 | – | 3 |
| | | (0.4190) | (0.0352) | (0.0998) | (0.2320) | (0.2905) | (0.0193) | (0.2186) | (0.5870) | | |
| | Caused | 1 | 3 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 17 |
| Period B: 1/8/1997–18/2/2000 | HON | – | 1.7449 | 1.7646 | 0.8824 | 3.6607 | 3.1092 | 3.4262 | 1.3332 | 3.9906 | 4 |
| | | | (0.1792) | (0.1758) | (0.4165) | (0.0287) | (0.0484) | (0.0358) | (0.2676) | (0.0211) | |
| | IND | 0.5197 | – | 0.2484 | 0.0325 | 0.4911 | 0.4973 | 0.3150 | 0.5202 | 0.1182 | 0 |
| | | (0.5960) | | (0.7804) | (0.9680) | (0.6132) | (0.6095) | (0.7304) | (0.5957) | (0.8885) | |
| | JAP | 0.8752 | 1.0326 | – | 0.2892 | 3.0892 | 0.5976 | 1.7231 | 1.1119 | 0.2866 | 1 |
| | | (0.4195) | (0.3593) | | (0.7494) | (0.0493) | (0.5518) | (0.1830) | (0.3324) | (0.7513) | |
| | KOR | 0.3800 | 0.9723 | 3.2733 | – | 0.0381 | 0.1450 | 0.4707 | 0.8068 | 1.7300 | 1 |
| | | (0.6847) | (0.3813) | (0.0414) | | (0.9626) | (0.8652) | (0.6257) | (0.4487) | (0.1818) | |
| | MAL | 0.1786 | 1.4918 | 0.3925 | 0.2670 | – | 0.2650 | 1.7222 | 2.0375 | 0.7478 | 0 |
| | | (0.8367) | (0.2292) | (0.6763) | (0.7661) | | (0.7677) | (0.1832) | (0.1350) | (0.4757) | |
| | PHI | 5.4192 | 1.5728 | 1.7096 | 2.3139 | 0.5657 | – | 0.4219 | 1.8785 | 1.0113 | 1 |
| | | (0.0056) | (0.2118) | (0.1855) | (0.1034) | (0.5695) | | (0.6567) | (0.1574) | (0.3669) | |
| | SIN | 0.6967 | 0.5426 | 5.5813 | 0.5731 | 2.8218 | 1.2947 | – | 2.3068 | 1.8058 | 2 |
| | | (0.5003) | (0.5826) | (0.0048) | (0.5653) | (0.0636) | (0.2779) | | (0.1041) | (0.1689) | |
| | TAI | 0.2034 | 5.0180 | 3.1816 | 2.0763 | 0.4949 | 1.6492 | 8.7499 | – | 3.6879 | 4 |
| | | (0.8162) | (0.0081) | (0.0452) | (0.1300) | (0.6109) | (0.1967) | (0.0003) | | (0.0280) | |
| | THA | 0.0313 | 1.4840 | 2.1293 | 2.5491 | 2.7517 | 1.5455 | 1.1804 | 3.5759 | – | 3 |
| | | (0.9691) | (0.2310) | (0.1235) | (0.0825) | (0.0680) | (0.2175) | (0.3108) | (0.0311) | | |
| | Caused | 1 | 1 | 3 | 1 | 4 | 1 | 2 | 1 | 2 | 16 |
| Period C: 1/1/1988–18/2/2000 | HON | – | 1.0435 | 1.1136 | 0.7904 | 0.4644 | 7.8933 | 4.6673 | 0.1282 | 2.5427 | 2 |
| | | | (0.3074) | (0.2917) | (0.3743) | (0.4958) | (0.0051) | (0.0311) | (0.7204) | (0.1113) | |
| | INDO | 0.2769 | – | 6.7642 | 0.0141 | 1.4033 | 0.9990 | 0.2927 | 0.2655 | 0.0259 | 1 |
| | | (0.5989) | | (0.0095) | (0.9054) | (0.2366) | (0.3179) | (0.5887) | (0.6065) | (0.8721) | |
| | JAP | 0.0073 | 0.6639 | – | 0.2417 | 1.2413 | 1.0652 | 0.0303 | 0.3555 | 0.0171 | 0 |
| | | (0.9319) | (0.4155) | | (0.6231) | (0.2656) | (0.3024) | (0.8618) | (0.5512) | (0.8958) | |
| | KOR | 2.6845 | 7.9317 | 2.5799 | – | 5.6731 | 0.2230 | 0.3442 | 1.0251 | 0.0492 | 2 |
| | | (0.1018) | (0.0050) | (0.1087) | | (0.0175) | (0.6369) | (0.5576) | (0.3117) | (0.8245) | |
| | MAL | 0.5118 | 0.3172 | 3.0564 | 0.2581 | – | 0.6649 | 0.0755 | 0.7471 | 0.9630 | 1 |
| | | (0.4746) | (0.5735) | (0.0809) | (0.6116) | | (0.4151) | (0.7835) | (0.3877) | (0.3268) | |
| | PHI | 0.1192 | 0.7599 | 1.4762 | 0.4265 | 3.6973 | – | 0.2083 | 3.7522 | 14.1321 | 3 |
| | | (0.7300) | (0.3837) | (0.2248) | (0.5139) | (0.0550) | | (0.6482) | (0.0532) | (0.0002) | |
| | SIN | 0.1313 | 3.8564 | 1.6266 | 0.0440 | 2.8080 | 0.5594 | – | 0.4772 | 1.0196 | 2 |
| | | (0.7171) | (0.0500) | (0.2026) | (0.8338) | (0.0943) | (0.4548) | | (0.4899) | (0.3130) | |
| | TAI | 0.9550 | 0.0079 | 0.0507 | 1.2907 | 0.0766 | 0.0097 | 2.1108 | – | 0.6690 | 0 |
| | | (0.3288) | (0.9292) | (0.8218) | (0.2563) | (0.7820) | (0.9214) | (0.1468) | | (0.4137) | |
| | THA | 1.0849 | 11.777 | 1.3239 | 3.4289 | 7.2499 | 10.0566 | 3.8322 | 0.0439 | – | 5 |
| | | (0.2980) | (0.0006) | (0.2503) | (0.0645) | (0.0073) | (0.0016) | (0.0507) | (0.8340) | | |
| | Caused | 0 | 3 | 2 | 1 | 4 | 2 | 2 | 1 | 1 | 16 |

Notes: Granger causality tests are conducted by adjusting the long-term cointegrating relationship by the ECM; figures in brackets are p-values; tests indicate Granger causality by row to column and Granger caused by column to row, for example, in the period 1/1/1988 – 27/7/97 Hong Kong (row) Granger causes three markets (Indonesia, Malaysia and Singapore) and is Granger caused by Korea (using a critical value of .10).

Since cointegration exists between all three sets of indices, Granger causality tests are performed on the basis of equation (5). $F$-statistics are calculated to test the null hypothesis that the first index series does not Granger cause the second, against the alternative hypothesis that the first index Granger causes the second. Calculated statistics and $p$-values for the markets are detailed in Table 3. The first matrix of test statistics in Table 3 relates to the period 1/1/1988 to 25/7/1997. Among the nine markets seventeen significant causal links are found (at the .10 level or lower). For example, column 4 shows that the Indonesian, Korean and Philippine markets affect the Malaysian market; the Taiwan market (column 8) is influenced by Korea and the Philippines; and the Hong Kong market (column 1) is influenced by Korea.

Further insights are gained by examining the rows in Table 3 indicating the effects of a particular market on all markets. It is evident that the Korean market is the most influential market in the Asian regional area, influencing Hong Kong, Indonesia, Philippines, Singapore and Taiwan. The least influential markets in terms of Granger-causality in the pre-crises period include Japan, Singapore and Taiwan. There is also an indication that there is feedback at play in several pairwise combinations: for example, the Philippines Granger-causes Thailand and Thailand Granger-causes the Philippines.

The second set of test statistics and $p$-values in Table 3 relates to the period since the onset of the Asian crises, while the third set relates to the entire sample period (ie. before and after the onset of the Thai currency crisis). The results in these periods are broadly comparable to those found earlier. Hong Kong and Taiwan are the markets that Granger cause the most other indices in the post-crises period, while Thailand Granger causes the most markets over the total sample. There is no change in the number of short-run causal links. One implication of the results in Table 3 is that there may be no gains from pairwise portfolio diversification between those countries where a significant causal relationship exists. Also since we have a finding of causality these markets must be seen as violating weak-form efficiency since one of the markets can help forecast the other. In all other cases, the absence of Granger causality implies that there are sufficient short-run differences between the markets for non-Asian investors to gain by portfolio diversification. However, these results should consider that Granger causality only indicates the most significant direct causal relationship. For example, it may be that markets such as Hong Kong influence non-Granger caused markets indirectly through other markets.

TABLE 4. *Generalised variance decomposition for Asian markets, 1/1/1988–25/7/1997*

| MKT | PER | HON | IND | JAP | KOR | MAL | PHI | SIN | TAI | THA | OTH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HON | 1 | 100.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 4 | 98.191 | 0.023 | 0.001 | 1.515 | 0.051 | 0.070 | 0.010 | 0.007 | 0.131 | 1.809 |
| | 12 | 98.191 | 0.023 | 0.001 | 1.515 | 0.051 | 0.070 | 0.010 | 0.007 | 0.131 | 1.809 |
| | 24 | 98.191 | 0.023 | 0.001 | 1.515 | 0.051 | 0.070 | 0.010 | 0.007 | 0.131 | 1.809 |
| IND | 1 | 2.845 | 97.155 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.845 |
| | 4 | 6.511 | 91.019 | 0.056 | 1.309 | 0.019 | 0.043 | 0.201 | 0.004 | 0.838 | 8.981 |
| | 12 | 6.511 | 91.019 | 0.056 | 1.309 | 0.019 | 0.043 | 0.201 | 0.004 | 0.838 | 8.981 |
| | 24 | 6.511 | 91.019 | 0.056 | 1.309 | 0.019 | 0.043 | 0.201 | 0.004 | 0.838 | 8.981 |
| JAP | 1 | 1.835 | 0.246 | 97.920 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.080 |
| | 4 | 1.975 | 1.860 | 94.487 | 0.506 | 0.032 | 0.256 | 0.165 | 0.197 | 0.522 | 5.513 |
| | 12 | 1.975 | 1.860 | 94.487 | 0.506 | 0.032 | 0.256 | 0.165 | 0.197 | 0.522 | 5.513 |
| | 24 | 1.975 | 1.860 | 94.487 | 0.506 | 0.032 | 0.256 | 0.165 | 0.197 | 0.522 | 5.513 |
| KOR | 1 | 1.699 | 1.288 | 2.692 | 94.322 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.678 |
| | 4 | 2.347 | 1.337 | 2.655 | 92.428 | 0.074 | 0.026 | 0.788 | 0.069 | 0.277 | 7.572 |
| | 12 | 2.348 | 1.337 | 2.655 | 92.428 | 0.074 | 0.026 | 0.788 | 0.069 | 0.277 | 7.572 |
| | 24 | 2.348 | 1.337 | 2.655 | 92.428 | 0.074 | 0.026 | 0.788 | 0.069 | 0.277 | 7.572 |
| MAL | 1 | 17.797 | 3.170 | 2.540 | 0.034 | 76.459 | 0.000 | 0.000 | 0.000 | 0.000 | 23.541 |
| | 4 | 18.803 | 3.199 | 2.424 | 1.880 | 70.812 | 2.521 | 0.098 | 0.009 | 0.253 | 29.188 |
| | 12 | 18.803 | 3.199 | 2.424 | 1.880 | 70.812 | 2.521 | 0.098 | 0.009 | 0.253 | 29.188 |
| | 24 | 18.803 | 3.199 | 2.424 | 1.880 | 70.812 | 2.521 | 0.098 | 0.009 | 0.253 | 29.188 |
| PHI | 1 | 10.053 | 4.051 | 0.016 | 1.035 | 4.933 | 79.912 | 0.000 | 0.000 | 0.000 | 20.088 |
| | 4 | 13.401 | 3.944 | 0.062 | 1.054 | 4.787 | 75.701 | 0.009 | 0.009 | 1.033 | 24.299 |
| | 12 | 13.401 | 3.944 | 0.062 | 1.054 | 4.787 | 75.701 | 0.009 | 0.009 | 1.033 | 24.299 |
| | 24 | 13.401 | 3.944 | 0.062 | 1.054 | 4.787 | 75.701 | 0.009 | 0.009 | 1.033 | 24.299 |
| SIN | 1 | 22.058 | 2.983 | 5.160 | 0.311 | 20.396 | 0.695 | 48.397 | 0.000 | 0.000 | 51.603 |
| | 4 | 23.955 | 2.882 | 4.949 | 1.053 | 19.471 | 1.145 | 46.233 | 0.015 | 0.298 | 53.767 |
| | 12 | 23.955 | 2.882 | 4.949 | 1.053 | 19.471 | 1.145 | 46.233 | 0.015 | 0.298 | 53.768 |
| | 24 | 23.955 | 2.882 | 4.949 | 1.053 | 19.471 | 1.145 | 46.233 | 0.015 | 0.298 | 53.768 |
| TAI | 1 | 1.256 | 0.025 | 0.466 | 0.318 | 0.129 | 0.842 | 0.347 | 96.615 | 0.000 | 3.385 |
| | 4 | 1.643 | 0.264 | 0.463 | 0.758 | 0.163 | 1.639 | 0.385 | 94.591 | 0.095 | 5.409 |
| | 12 | 1.643 | 0.264 | 0.463 | 0.758 | 0.163 | 1.639 | 0.385 | 94.590 | 0.095 | 5.410 |
| | 24 | 1.643 | 0.264 | 0.463 | 0.758 | 0.163 | 1.639 | 0.385 | 94.590 | 0.095 | 5.410 |
| THA | 1 | 13.320 | 1.672 | 0.963 | 0.349 | 10.940 | 1.514 | 4.674 | 0.269 | 66.299 | 33.701 |
| | 4 | 13.671 | 1.613 | 0.961 | 0.360 | 10.662 | 4.062 | 4.497 | 0.460 | 63.714 | 36.286 |
| | 12 | 13.671 | 1.613 | 0.961 | 0.360 | 10.662 | 4.062 | 4.497 | 0.460 | 63.714 | 36.286 |
| | 24 | 13.671 | 1.613 | 0.961 | 0.360 | 10.662 | 4.062 | 4.497 | 0.460 | 63.714 | 36.286 |
| Mean | | 19.788 | 11.917 | 11.887 | 11.082 | 11.974 | 9.426 | 5.849 | 10.638 | 7.438 | 18.372 |

Notes: The decomposition order is indicated by column; the final column (OTH) is the percentage of forecast error variance of the market indicated in first column (MKT) explained by all other markets except the market's own innovations; the periods (PER) in the second column are in weeks.

Table 4 presents the decomposition of the forecast error variance for 1-week, 4-week, 12-week and 24-week ahead horizons for the Asian equity markets in the pre-crises period period. Each row indicates the percentage of forecast error variance explained by the column heading for the market indicated in the first column. For example, at the 1-week horizon, the variance in the Hong Kong market is completely explained by its own innovations, whereas in the remaining markets some percentage of variance is explained by innovations in other markets. Put differently, other markets explain 2.8 percent of variance in the Indonesian market, 2.1 for Japan, 5.7 for Korea, 23.5 for Malaysia, 20.1 for the Philippines, 51.6 for Singapore, 3.4 for Taiwan, and 33.7 for Thailand. These would indicate that the Hong Kong market is the least influenced by innovation in other markets in the pre-crises period, while the Singaporean market is the most sensitive. Overall, markets other than 'home' markets explain on average 18.4 percent of variance in Asian markets in the pre-crises period. Also on average, the Hong Kong market explains 19.8 percent of variation in other markets, while the Thai market only explains 7.4 percent and the Philippines 9.4 percent.

TABLE 5. *Generalised variance decomposition for Asian markets, 1/8/1997–18/2/2000*

| MKT | PER | HON | IND | JAP | KOR | MAL | PHI | SIN | TAI | THA | OTH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HON | 1 | 84.118 | 15.882 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 15.882 |
| | 4 | 62.597 | 14.582 | 0.372 | 2.496 | 0.914 | 0.865 | 1.084 | 14.344 | 2.746 | 37.403 |
| | 12 | 58.528 | 15.427 | 0.530 | 3.184 | 0.892 | 0.882 | 1.745 | 15.972 | 2.840 | 41.472 |
| | 24 | 58.336 | 15.698 | 0.529 | 3.176 | 0.891 | 0.880 | 1.743 | 15.917 | 2.830 | 41.664 |
| IND | 1 | 0.000 | 100.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 4 | 1.756 | 95.022 | 0.283 | 0.055 | 0.201 | 1.645 | 0.676 | 0.287 | 0.074 | 4.978 |
| | 12 | 2.795 | 93.800 | 0.229 | 0.541 | 0.338 | 1.000 | 1.007 | 0.248 | 0.042 | 6.200 |
| | 24 | 2.908 | 93.728 | 0.207 | 0.581 | 0.366 | 0.906 | 1.024 | 0.241 | 0.039 | 6.272 |
| JAP | 1 | 13.579 | 2.410 | 84.011 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 15.989 |
| | 4 | 11.809 | 1.918 | 58.302 | 8.252 | 0.183 | 0.591 | 5.093 | 7.076 | 6.775 | 41.698 |
| | 12 | 11.362 | 2.990 | 55.363 | 8.147 | 0.526 | 0.951 | 5.243 | 8.906 | 6.512 | 44.637 |
| | 24 | 11.352 | 3.109 | 55.290 | 8.137 | 0.528 | 0.950 | 5.237 | 8.894 | 6.503 | 44.710 |
| KOR | 1 | 3.961 | 4.245 | 1.951 | 89.843 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 10.157 |
| | 4 | 4.268 | 5.110 | 2.706 | 72.680 | 1.159 | 2.447 | 0.305 | 7.913 | 3.412 | 27.320 |
| | 12 | 4.296 | 5.765 | 2.780 | 71.760 | 1.254 | 2.460 | 0.411 | 7.872 | 3.401 | 28.240 |
| | 24 | 4.296 | 5.811 | 2.779 | 71.723 | 1.254 | 2.459 | 0.411 | 7.868 | 3.399 | 28.277 |
| MAL | 1 | 2.411 | 18.292 | 0.251 | 1.298 | 77.748 | 0.000 | 0.000 | 0.000 | 0.000 | 22.252 |
| | 4 | 2.004 | 21.800 | 5.425 | 1.196 | 60.139 | 1.816 | 2.499 | 0.340 | 4.781 | 39.861 |
| | 12 | 2.051 | 22.060 | 5.691 | 1.721 | 58.745 | 1.905 | 2.489 | 0.678 | 4.660 | 41.255 |
| | 24 | 2.053 | 22.199 | 5.681 | 1.719 | 58.631 | 1.903 | 2.486 | 0.677 | 4.650 | 41.369 |
| PHI | 1 | 10.888 | 40.295 | 0.832 | 0.064 | 3.782 | 44.139 | 0.000 | 0.000 | 0.000 | 55.861 |
| | 4 | 10.213 | 35.468 | 2.366 | 0.573 | 3.586 | 41.585 | 0.944 | 3.765 | 1.500 | 58.415 |
| | 12 | 9.954 | 35.649 | 2.438 | 1.083 | 3.543 | 40.402 | 0.990 | 4.286 | 1.655 | 59.598 |
| | 24 | 9.933 | 35.838 | 2.430 | 1.082 | 3.533 | 40.272 | 0.990 | 4.272 | 1.650 | 59.728 |
| SIN | 1 | 25.606 | 20.706 | 1.322 | 3.153 | 1.398 | 2.146 | 45.670 | 0.000 | 0.000 | 54.330 |
| | 4 | 19.344 | 24.264 | 1.741 | 2.117 | 1.346 | 2.290 | 28.475 | 16.722 | 3.700 | 71.525 |
| | 12 | 18.472 | 24.737 | 2.177 | 2.740 | 1.457 | 2.237 | 27.275 | 17.177 | 3.729 | 72.725 |
| | 24 | 18.402 | 25.051 | 2.168 | 2.731 | 1.453 | 2.229 | 27.155 | 17.099 | 3.712 | 72.845 |
| TAI | 1 | 7.554 | 2.874 | 0.006 | 2.359 | 6.827 | 0.028 | 0.049 | 80.303 | 0.000 | 19.697 |
| | 4 | 6.550 | 2.944 | 5.115 | 4.807 | 6.172 | 0.269 | 1.256 | 66.567 | 6.320 | 33.433 |
| | 12 | 6.370 | 3.346 | 5.032 | 5.474 | 6.380 | 0.464 | 1.242 | 65.282 | 6.411 | 34.718 |
| | 24 | 6.367 | 3.418 | 5.029 | 5.470 | 6.376 | 0.464 | 1.242 | 65.229 | 6.405 | 34.771 |
| THA | 1 | 8.418 | 31.939 | 1.657 | 2.798 | 2.431 | 1.621 | 0.998 | 0.000 | 50.138 | 49.862 |
| | 4 | 6.317 | 32.284 | 1.129 | 2.615 | 4.353 | 2.248 | 1.707 | 8.346 | 41.001 | 58.999 |
| | 12 | 6.001 | 33.584 | 1.994 | 3.389 | 4.150 | 2.283 | 1.687 | 8.384 | 38.526 | 61.474 |
| | 24 | 5.985 | 33.984 | 1.982 | 3.373 | 4.126 | 2.270 | 1.684 | 8.329 | 38.267 | 61.733 |
| Avg. | | 14.468 | 26.284 | 8.883 | 10.843 | 9.019 | 5.739 | 4.801 | 12.861 | 7.102 | 38.871 |

Notes: The decomposition order is indicated by column; the final column (OTH) is the percentage of forecast error variance of the market indicated in first column (MKT) explained by all other markets except the market's own innovations; the periods (PER) in the second column are in weeks.

In the post-crises period (Table 5) dramatically different results are obtained through the forecast variance decomposition. To start with, some 38.9 percent of the variation in markets other than the 'home' market are explained by changes in other Asian markets (as against 18.4 in the pre-crises period). This increase in interrelationships in other markets also holds for individual economies. For example, Hong Kong in the pre-crises period was wholly explained by innovations in its own market, but in the post-crises period other markets explain 15.9 percent of the forecast variance. Similarly, innovations in other markets previously explained 3.4 percent of the variation in the Taiwan market; this has risen to 19.7 percent in the post-crises period. Similar findings hold for all other markets. In the only other known study of Asian financial integration in the post-crisis period, Baig and Goldfajn (1998: 42) concluded:

> The Asian crises suggest that during a period of financial market instability, market participants tend to move together across a range of countries. Shocks originating from one market readily get transmitted to other markets, thus becoming a source of substantial instability.

Nevertheless, while Baig and Goldfajn (1998: 42) found evidence of substantial contagion in the foreign debt markets, "…the evidence on stock market contagion is more tentative". The exception to this finding is Indonesia. In the pre-crises period, innovations in other markets explained 2.5 percent of the variance in the Indonesian market, and this fallen to zero in the post-crises period. In a comparable study, Janakiramanan and Lamba (1998: 159) also discovered that "only the relatively isolated market of Indonesia exhibits low and statistically insignificant correlations with most other markets".

The evidence presented reinforces the suggestion that at at least some emerging markets in the Asian region are relatively isolated, and therefore prospects for international portfolio diversification still exist. Markets least explained by innovations in other markets include Indonesia, Korea, Malaysia and Taiwan. This effect also appears to persist for considerable periods of time. The results are also interesting in that they illuminate aspects of market interaction not indicated by the Granger causality tests. A notable example is the observation that Thailand Granger-causes five other markets in the post-crises period. In the forecast variance decomposition of analysis, the Thai market also significantly influences several markets after 24 weeks, especially itself and Indonesia, but the variance explained for Hong Kong, Japan, Korea, Malaysia, the Philippines, Singapore and Taiwan is less than ten percent.

## 5. Concluding remarks

This paper investigates long-term and short-term relationships among nine Asian equity markets during the period 1988 to 2000. Three of these markets are regarded as developed (Hong Kong, Japan and Singapore) while the majority are categorised as emerging markets (namely, Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand). Multivariate cointegrating techniques are used to establish long-term relationships among these markets and Granger caudsality tests are used to measure causal relationships in the short-term within an error-correcting model (ECM). The results indicate, as expected, that the Asian equity markets are highly integrated, both before and after the recent crises. This long-term interdependency appear to be have dramatically increased in the period during and after the Asian crises. Possible reasons include long-standing trends in trade and investment interaction, and the more recent convergence in monetary policies and the almost universal process of microeconomic reform flowing from the crises themselves.

The findings obtained in this paper have obvious implications for the purported benefits of international portfolio diversification among the several Asian equity markets. In effect, the strong short-term causality and long-term linkages among the national markets would indicate that the returns from such a strategy have diminished markedly. However, the results also suggest that opportunities for diversification may still exist, especially in some of the smaller markets. This is further reinforced by the results of a decomposition of variance analysis that indicate that a distinguishing characteristic of some of the smaller markets is the extremely low level of variance explained by other markets (ie. Indonesia). Nevertheless, even in the larger economies, say Hong Kong, Japan and Korea, only moderate levels of variance are explained by other markets for relatively long periods of time. This highlights further opportunities for portfolio diversification by international investors.

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